

Climate Change and the India-China Rivalry

# Melting Mountains, Mounting Tensions

*Investigating how climate change will impact the rivalry between nuclear powers India and China and the consequent threats to security*



**Woodwell Climate  
Research Center**

THE  
CONVERGING  
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RISKS**

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# Melting Mountains, Mounting Tensions

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Traveling along the Brahmaputra River. Rita Willaert, 2007*

# Key Findings

Indian Army trucks at Khardung La, near Leh, Jammu and Kashmir, India. Robert Szymanski, 2020

The rivalry between nuclear powers India and China is among the most fraught in Asia, and tensions are rising. This study, integrating climate science and security analysis, finds that climate change will enhance material and perceptual risks by 2040, increasing chances of conflict but also presenting opportunities for cooperation. The key risks identified are:

- In the Brahmaputra River Basin, climate change will raise the risk of downstream floods during the monsoon season, especially in July and September, which could lead to Indian perceptions of water manipulation by China. China's lack of transparency in its dam projects on transboundary rivers, and severe distrust between the two rivals, create additional risks of misperception and attendant security tensions.
- China's Belt and Road Initiative dam projects on the Indus River in Pakistani-held Kashmir will be viable through late in the century, helping sharpen South Asia's rivalries and increase regional instability.
- A strong warming trend in the harsh western border region will increase the viability of military patrols, and therefore could enhance the potential for violent clashes between nations, and more frequent and hard-to-predict landslides and glacial lake outburst floods could further endanger troops.

To mitigate perceptual and material risks, the two countries should initiate a dialogue, with the aim of agreements on regular, granular data exchange, including full transparency on dam projects, establishing joint early warning and response mechanisms for natural disasters, and incorporating best practices on river management. Ultimately, China and India should also work toward river basin treaties extending to all relevant riparian states for both the Brahmaputra and the Indus.

# China and India: An Escalating Rivalry

Asian giants China and India have had a difficult relationship since their border war in 1962. The contested border (the Line of Actual Control, or the LAC) and Chinese support for India's rival Pakistan, including aid for Islamabad's nuclear weapons program and building of major dam projects as a part of Beijing's Belt and Road Initiative (BRI), have been key drivers of the rivalry.

A bilateral thaw emerged in the late 1980s but began to erode in 2010, with smaller military face-offs in which both sides accused the other of territorial intrusions. Tensions surged in the spring of 2020, when Chinese troops allegedly seized hundreds of square kilometers of Indian-controlled territory in the Ladakh region, triggering a military clash in June that culminated in the deaths of 20 Indian and four Chinese troops.<sup>1</sup> These deaths, the first on the India-China border in 45 years, thus marked a major security escalation. Both sides deployed

tens of thousands of troops at the LAC in what appears to be a long-term build-up at several key locations, though a disengagement agreement was reached recently for one of the face-off locations (Figure 1).<sup>2</sup>

Winters are harsh on the China-India border, particularly in the west, with elevations above 4500 meters. Temperatures of -30°C to -40°C (-22°F to -40°F) are made even harsher by wind chill and lack of oxygen. Resulting health issues have contributed to a turnover rate of up to 20% on the Indian side, spurring the Indian army to rotate troops every two weeks.<sup>3</sup> Chinese troops are better equipped than their Indian counterparts. However, even with high-tech gear, smart-thermal housing, regular oxygen therapy and mechanical exoskeleton suits, conditions remain challenging.<sup>4</sup>

Figure 1: Key conflict locations and strategic infrastructure in the India-China border area.

## Western Border Region



## Eastern Border Region





A flooded area by  
Morigaon, Assam, India.  
Talukdar David, 2020

Complicating the situation is the fact that China and India are both nuclear weapons states.<sup>5</sup> To date, the rivalry has not involved nuclear signaling, due to the two countries' declared No-First Use policies and their common practice of separating warheads from delivery vehicles. However, the nuclear factor may become more prominent in wake of recent tensions.<sup>6</sup>

The Brahmaputra/Yarlung Tsangpo and Indus Rivers, shared between the rivals, are additional sites of contention. No accord for transboundary river management exists between China and India for the Brahmaputra River Basin, and Beijing's mega-project to divert large volumes of water from the Yangtze River to its arid northern regions, the South-to-North Water Diversion Project,<sup>7</sup> has generated concern in India that the Brahmaputra could be next. China's November 2020 announcement of a 60 GW hydroelectric project at the Great Bend, just 40 km north of the border with India, has sparked apprehension in India. In the Indus River Basin, China and its ally Pakistan are planning six major BRI dams, four of which are directly on the Indus River (Figure 1). India is strongly opposed to dams located in territory it claims. Thus, climate impacts on their viability have significant security implications for the India-China rivalry.

## Climate Change: A Threat Multiplier

Climate change is a fundamental threat to infrastructure, human health, water resources and food security, as highlighted recently by the U.S. intelligence community and in the World Climate and Security Report among others.<sup>8</sup> In South Asia, climate change will drive increasingly deadly heat waves and worsening droughts. India's current water crisis, brought on by inefficient water usage, poor infrastructure, and water contamination, will be made even more unbearable by climate change. The warming Indian Ocean will fuel stronger cyclones and sea level rise will generate higher storm surges, causing devastating coastal flooding, particularly in low-lying urban areas without sufficient flood defense infrastructure. Absent concerted mitigation and adaptation, conflict could become imminent as climate change disrupts economies and fuels competition for resources.

In the border region, climate change is a risk multiplier that will further complicate existing water resource challenges. Rapid warming in this region has already begun to disrupt seasonal river flow. Glaciers that once provided a steady flow of meltwater through the spring and summer are now retreating, and deadly glacial lake outburst floods—triggered by landslides (often caused by extreme precipitation) or glacial calving events—are also on the rise. The waters of the Brahmaputra to the east and the Indus to the west are shared by India and China, and the respective transboundary basins are experiencing increased water consumption as populations and economies grow in South Asia. The already flood-prone Brahmaputra River Basin will face extreme rainfall events during the monsoon season—which may be misinterpreted by downstream Indian populations as Chinese water manipulation, heightening political tensions.

# Climate Projections: Warming and Floods

A new series of case studies, of which this is the first, stems from climate projections that show more specific, granular effects in key regions than have been available to date. These are coupled with security analysis on the impact of these climate change effects on conflict zones involving nuclear states. This study (detailed here and in the appendix) projects changes in precipitation, discharge, temperature, and wind in 2030 and 2040 as compared to a 2010 baseline, for the India-China border region, the Indus River Basin, and the Brahmaputra River Basin.<sup>9</sup> These two time horizons present tractable and foreseeable points for assessing the intersections of security and climate in the region. The synthesis of security analysis and climate projections provide a foundation for projections on likely security impacts in the next two decades.

## The Western Border Region

Temperature and wind projections in the harsh western border region offer insight into the adversity troops might face in the future:

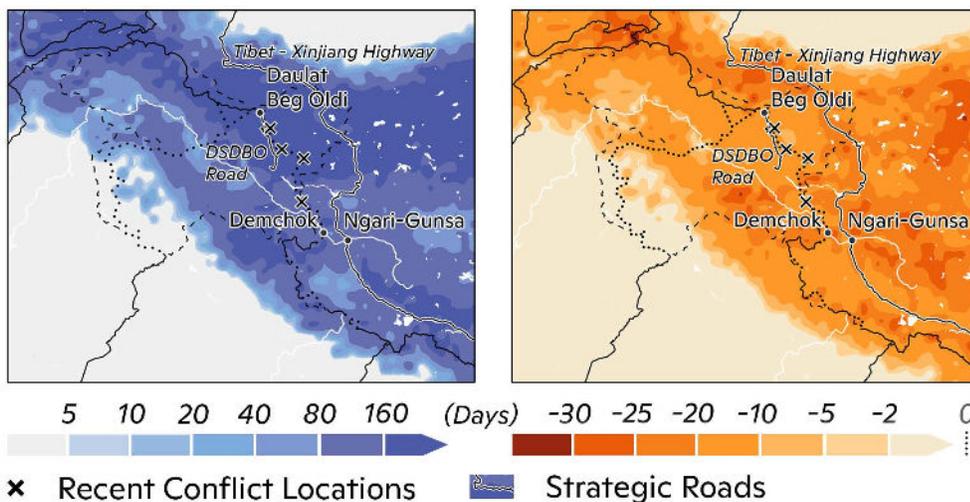
- Substantial warming is projected by 2040.<sup>10</sup> The border's southern portion (near Demchok in Ladakh and the states of Himachal Pradesh and Uttarakhand) warms slightly more than the particularly security-sensitive Depsang Plains in the north (Figure 2). This warming trend could make combat easier for soldiers deployed in the region in winter—potentially helping Indian troops overcome their current disadvantage in protective gear and equipment. However, warmer weather will also enable more military patrols, thus increasing opportunities for clashes, making the need for a durable border settlement more urgent.
- All along the mountainous border, troops will also face threats of hazardous glacial lake outburst floods (GLOFs). GLOFs can be triggered suddenly by slope failures or ice calving, events that are linked to warming temperatures. A February 2021 flash flood in India's Uttarakhand state which killed scores of people may have been caused by a GLOF,<sup>11</sup> highlighting the danger of these difficult-to-predict events.

The western border is also adjacent to the Indus River (Figure 1), which originates in Tibet, and flows through Ladakh before crossing into Pakistani-held Gilgit-Baltistan and then into Pakistan proper. In the Indus River Basin, climate projections indicate:

- Glacier runoff contributes a large fraction (40%)<sup>12</sup> to streamflow in the Indus River Basin (Figure A1). Glacier melt is projected to increase significantly in the near and mid-term projections until approximately 2060, after which it falls off to near-2010 levels at the end of the century (Figure A2).
- The Indus River discharge (i.e., volumetric rate of water flow) will remain similar or increase through the end of the century.

These two climate impacts ensure sustained or enhanced flow in the Indus which have the following implications for regional security and geopolitics:

- China’s planned BRI dam projects in Pakistani-held territory will remain viable and productive through the century and will provide ongoing incentives to continue such dam-building.
- The continued China-Pakistan collaboration on dam-building and associated BRI projects will help entrench the India-focused China-Pakistan alliance and could sharpen South Asia’s rivalries.



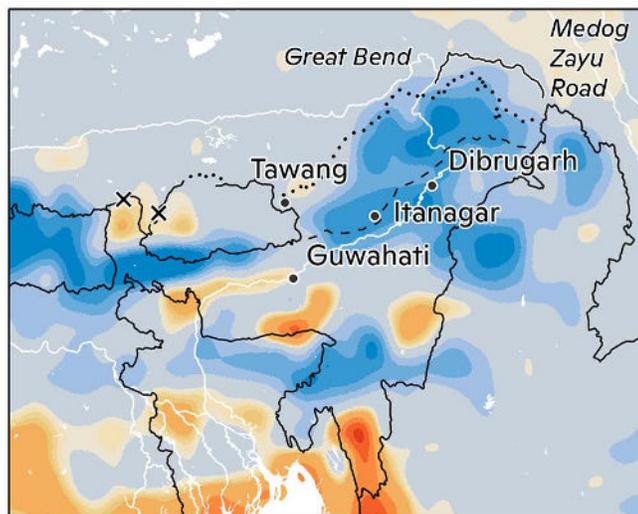
**Figure 2:**

Annual number of days with windchill temperature below -18°F in the 2010 period (left) and the change from 2010 to 2040 (right). Climate projections show substantial warming on the western border that could potentially increase opportunities for troop patrols and clashes — and expose troops to GLOFs.

# The Eastern Border Region

In the Brahmaputra River Basin, climate projections suggest a more volatile future:

- The Brahmaputra River Basin will continue to be predominantly fed by monsoon precipitation rather than by glacier melt (Figure A3). There will, however, be a substantial increase in extreme rainfall (Figure 3), especially in July and south of the Great Bend.
- The downstream Indian states of Assam and Arunachal Pradesh have a history of monsoon-season flooding, and the projected increases in July extreme rainfall—and to a lesser extent, September discharge at Guwahati (Figure A3a)—will result in an even higher likelihood of severe floods (Figures 3 and A3b).
- Heightened flood risk will particularly affect the nearly 40% of Assam which is already flood-prone, including the major cities of Guwahati and Dibrugarh. Regular flooding already requires intervention by the Indian National Disaster Response Force. An enhanced flood event can raise suspicions in India of water manipulation by China, though the driver may well be climate change.
- In contrast, while peak glacier runoff is currently in sync with the monsoon season (Figure A3b), it will begin to decrease rapidly around 2040 (Figure A2). This reduction, centered on July and August, will partially mitigate monsoon season flood risk.



**Figure 3:**

Maps of the difference in daily 99th percentile precipitation from 2010 to 2040 due to climate change!<sup>3</sup> Darker blue areas indicate locations more likely to experience extreme rainfall.



# Dams, Climate Change and Security



The Brahmaputra River Basin is the backdrop for a set of risks which, if not proactively managed, could push the two countries toward further conflict. First, climate impacts (chiefly, enhanced extreme rainfall episodes and glacier melt) will increase discharge and the potential for flooding throughout the lower portion of the basin. Second, new dams—initiated as part of China’s quest for clean energy—have the potential to materially impact downstream communities. This is especially plausible if, as seems likely, the proposed Great Bend dam requires substantial water storage. India worries about flooding triggered by flow manipulation by China, willful or otherwise, and water shortages lasting for months or years during the dam-filling process. The dam will also degrade downstream agricultural soils due to blockage of sedimentation.<sup>14</sup>

Most notably, however, the severe mistrust and dearth of water management institutions between the two countries invites misperceptions about each other’s intentions. As much as 65% of annual precipitation in the Brahmaputra River Basin falls in India, with China receiving only 21%.<sup>15</sup> Thus China is not the origin of most flooding in the region. But a major flood event in India could be construed as deliberate Chinese flow manipulation, regardless of whether this is objectively true. This gap between reality and perception is just the sort of spark that could raise tensions and help ignite conflict.

Ironically, China’s commitment to achieve net-zero emissions by 2060 is a driver of the 60 GW Great Bend dam. Nearly three times the size of the Three Gorges dam, the project is located at a site of major hydropower potential.<sup>16</sup> While China has already constructed the much smaller Zangmu dam upstream, with three other similar dams being built, announcement of the Great Bend dam has sparked particular consternation in downstream India and Bangladesh.

Hikers at Biafo Glacier, Karakoram Mountains, Pakistan. Vasiq Ekbal, 2013

For this study, five hydrology experts with experience analyzing Chinese projects were interviewed to assess the potential downstream impact of the proposed dam. Most agreed that, though characterized as run-of-the-river (e.g., a hydroelectric facility requiring little or no water storage), the dam is likely to require substantial storage. The hydropower system would be expected to collect water during the monsoon season and release it during the dry season in order to maintain at least minimal power generation throughout the year. This operational imperative would typically lower the volatility of downstream discharge and thus be beneficial to downstream populations in India. Bad-faith water manipulation is theoretically possible, but experts are divided on whether such action could be sizable enough to create significant damage downstream.

Of concern is that a dam of such magnitude could yield unintended material consequences. These include seismic impacts and the blockage of sedimentation. The massive Three Gorges dam triggered a remarkable increase in seismic activity in an area understood to have only low-level activity prior to its completion.<sup>17</sup> The region encompassing the Great Bend is already known to be seismically unstable.<sup>18</sup> A major earthquake could fracture dams and trigger catastrophic floods downstream. The reduction of silt flows will also likely have major downstream impacts over time, constraining soil fertility and eroding the integrity of riverbanks in India's state of Assam, potentially adding to tensions.

India's planned 10 GW dam in Arunachal Pradesh, announced in response to the Great Bend dam, may never be built, considering long delays in the construction of smaller Indian dams. According to experts interviewed, the Indian dam would also not be an effective counter. Instead, India may be relying on the doctrine of "prior appropriation," in which the

party that first makes "beneficial use" of the water it is accorded rights to and is acknowledged as such by international law.<sup>19</sup>

Water diversion is another Indian concern. China's arid northern regions are expected to suffer greater droughts due to climate change.<sup>20</sup> Most experts interviewed were skeptical of the feasibility of a diversion project to China's arid regions. Yet all identified China's general lack of transparency in conducting large-scale infrastructure projects as fuel for suspicions in downstream states—as has been the experience of Southeast Asian countries regarding Chinese dams on the Mekong River.

The combination of material and perceived factors increases the risk of conflict between Asia's two biggest nuclear powers. Material impacts of climate change, which enhance the risk of flooding, converging with Chinese dam projects in Tibet and the Kashmir region, constitute legitimate concerns for downstream actor India. But the manifest dearth of trust and China's opaque approach toward sharing hydrological and dam project data could be a catalyst for spikes in tensions. If China and India are able to overcome this mistrust they might manage the Indus and Brahmaputra River Basins for mutual gains, including regulating seasonal flows, managing floods, and trading electricity.

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Construction at Tarbela Dam, Khyber Pakhtunkhwa, Pakistan. U.S. Embassy Pakistan, 2010



# Recommendations: Averting Climate Conflict in Asia

How might China and India step back from this cycle of tension and alienation in which climate change is playing an increasing part?

The material impacts of climate change on temperature, river flows and planned Chinese dams are significant and, in practical terms, unavoidable. But perceptual risks can be greatly reduced by introducing transparency, predictability, and collaboration in riparian system management: key elements to building the confidence and trust needed to manage inevitable future disputes.

- The two governments should commit politically to creating and institutionalizing processes for data-based joint management of shared river basins. The starting point would be regular, comprehensive data collection and monitoring, with a focus on data from the hydrologically-relevant high rainfall areas south of the Great Bend on the Yarlung Tsangpo.<sup>21</sup> The existing Expert Level Mechanism could take on this expanded mission. A second step would be adoption of “rules of engagement” for dam operations and related cross-border communication, including publishing environmental and social impact data for all hydrological projects above an agreed MW level. Developments might be presented at regular forums convening hydrological experts, commercial power operators, scientists, local communities and civil society stakeholders. Implementation of internationally recognized best practices in river management could provide further grounds for transparency and collaboration. Particular attention should be paid to hydrological regimes, fish migration, biodiversity, reservoir sedimentation, and reservoir impoundment.<sup>22</sup>
- The two militaries should consider regular dialogue on the state of the environment in the LAC, including evidence of what could trigger floods, avalanches or other threats to military personnel or civilians. Holding such dialogue at a sub-command level or incorporating it within the existing military-to-military dialogue formats—rather than at a political level—could reinforce regularity and enhance trust.
- Chinese and Indian first-responder organizations should establish two collaborative mechanisms: (1) a joint early warning system for future natural disasters in the LAC, and (2) concomitant coordination procedures for disaster response and emergency relief. The first builds upon warnings that China has occasionally provided in the past.<sup>23</sup> The latter would enable joint rescue efforts upon request for civilians or soldiers trapped by avalanches or natural disasters. In addition to obvious humanitarian benefits, such systems would also generate denser engagement of officials; build trust; and lessen the likelihood of a fundamental attribution error downstream.

- China and India could consider enhancing the number of weather stations in the border region and ensure the public release of reliable, continuous weather station data. This would make a material contribution to scientific projections, and provide an open information base for observers on both sides to identify time-sensitive threats to the physical stability of the region.
- The international community might offer to aid the two countries, should they need it and be willing, in monitoring the LAC region solely for the purpose of detecting imminent natural disasters which threaten populations in the area.
- A process for new and extended treaties over the entirety of the Brahmaputra and Indus River Basins with all relevant riparian states ought to be the longer-term aspirational goal. This will be highly challenging given the fractious geopolitics of the region but, if the parties can be persuaded, the World Bank could play a role as a facilitator for such a process.

As an upstream actor, it is incumbent upon China to make the first move. China could take India into confidence on its planned dam projects, particularly the sizable Great Bend dam in Tibet and planned dams in Pakistani-held Kashmir. A measured but increasing normalization of data-sharing and communication could bolster confidence toward more ambitious goals, such as China selling hydroelectric power to Indian states downstream. These commitments in turn would provide political space for institutionalizing data-sharing and communications, and eventually, for treaties on shared river basins. The United States and the international community could discreetly support this process.

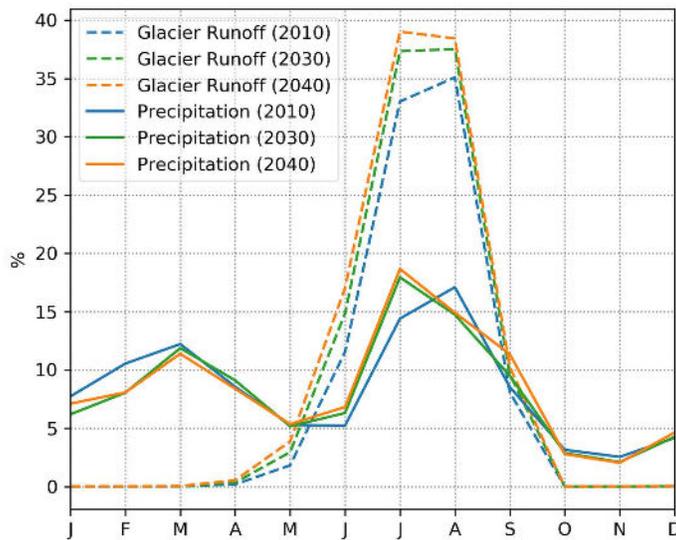
## Conclusion

The myriad systemic threats presented by climate change demand multi-faceted, systemic responses. But while climate impacts are predictable, human behavior is not. India and China would benefit from a process of cooperation on climate impacts on their shared river basins as a means to build trust in what is an otherwise tense relationship. The international community should support such steps practically and politically as a means to peace and stability in a predictably uncertain world.

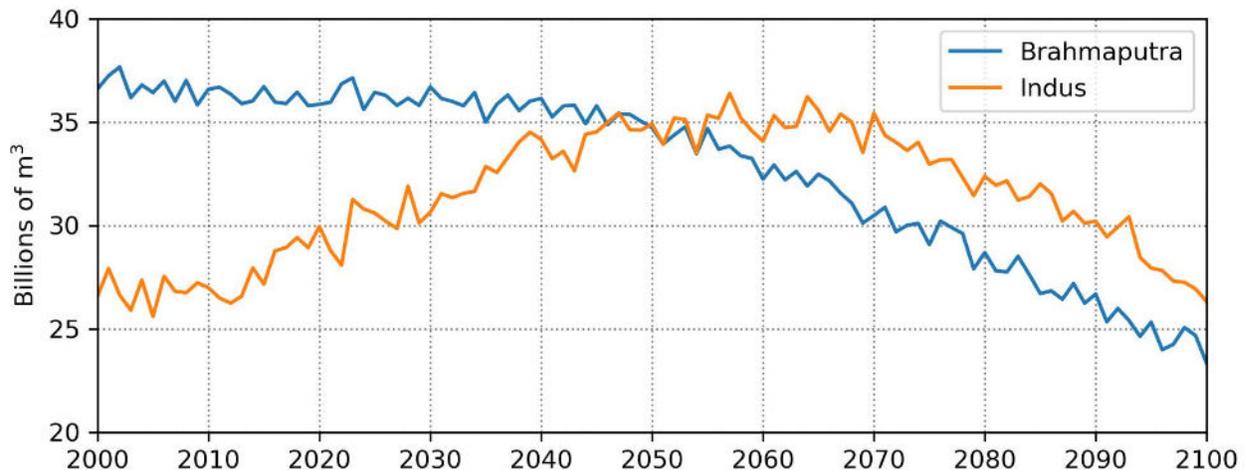
# Appendix: The Indus and Brahmaputra Basins

## The Indus River Basin

The Indus River Basin (IRB) receives the majority of its precipitation during the summer monsoon season, although unlike the Brahmaputra River Basin (BRB), the IRB also receives significant precipitation in the winter (Figure A1). With seasonal precipitation peaks in the upper IRB remaining relatively unchanged in the time horizon examined, increased summer glacier runoff has the potential to raise flood risk.



**Figure A1:** IRB monthly precipitation (solid) and glacier runoff (dashed) for 2010, 2030, and 2040. Values are expressed as a percentage of the 2001-2050 mean annual total.<sup>24</sup>An increase in peak glacier runoff can enhance flood risk.



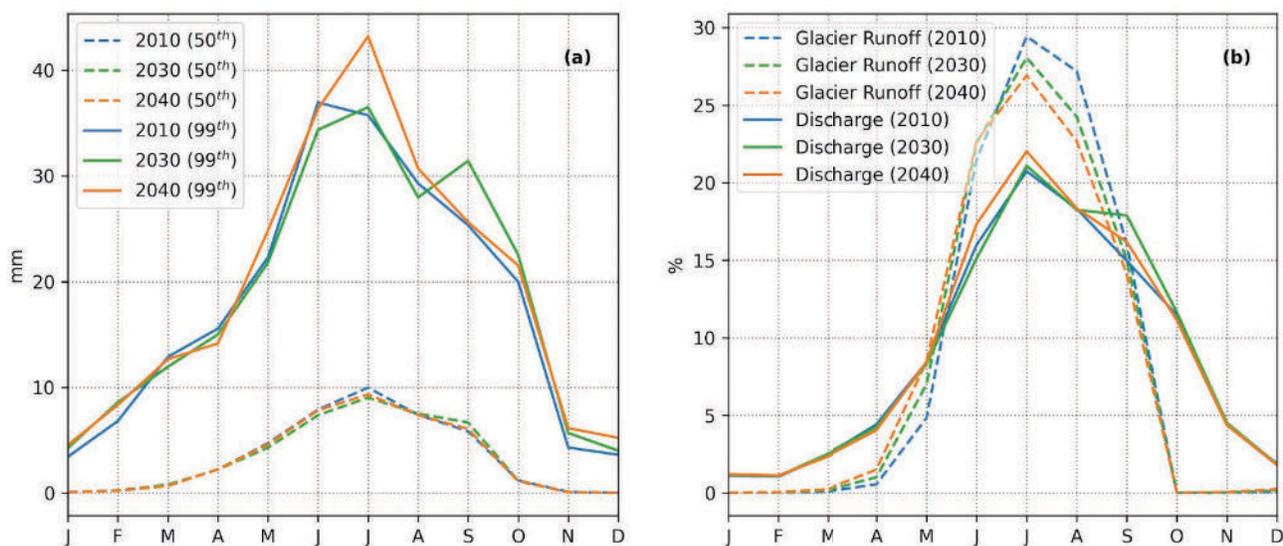
**Figure A2:** Total annual glacier runoff volume for the BRB (blue) and IRB (orange) from 2000 to 2100. Glacier runoff will increase in the IRB throughout most of the 21st century, whereas glacier runoff in the BRB has already peaked and is projected to decrease throughout the century.

# The Brahmaputra River Basin

In the eastern border region, the BRB is predominantly fed by precipitation in the monsoon season (June through September). Although glacier and snow melt contribute an estimated one-quarter to one-third of total discharge in the upper BRB annually,<sup>25</sup> the seasonal cycle of precipitation does not shift significantly from the 2010 baseline to the 2030 or 2040 projections.

Throughout the BRB, extreme precipitation is expected to increase in the mid-term (2040) projection (Figure 3). Extreme precipitation changes are most prominent in the Himalayas in the upper BRB, including Arunachal Pradesh and near the Great Bend, where extreme precipitation increases by over 10 mm (up to 20% of 2010 baseline values). On the other hand, median precipitation is expected to decrease slightly—ca. 6% decrease in the July peak, albeit against a large year-to-year variability (Figure A3a). Paired with the rapid decrease in glacier runoff beginning around 2040 (Figure A2), this may exacerbate longer-term water scarcity issues.

The projected monthly maximum discharge at Guwahati, the largest city in India’s northeast region, reflects the general increasing trends observed in extreme precipitation (Figure A3b) and discharge throughout the entire lower BRB (not shown). As with basin-averaged precipitation, monthly maximum discharge remains relatively unchanged in the future outside of the monsoon season. In the near-term (2030) projection, monthly maximum discharge varies slightly relative to the 2010 baseline, but increases significantly in September. In the mid-term (2040) projection, a more consistent increase is observed throughout the monsoon season.



**Figure A3:**

The (a) seasonal cycle of monthly median (dashed lines) and extreme (solid lines) precipitation for 2010, 2030, and 2040 for the entire BRB and (b) maximum monthly discharge taken at Guwahati (solid) and glacier runoff for the BRB (dashed) for 2010, 2030, and 2040. In panel (b), values are expressed as a percentage of the 2001-2050 mean annual total.<sup>26</sup> Peak glacier runoff coincides with the monsoon season, increasing flood risk. Values are expressed as a percentage of the 2001-2050 mean annual total.

## Endnotes

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- [1] Kunal Purohit and Agencies, “20 Indian soldiers killed in border clash with Chinese troops” *South China Morning Post*, June 16, 2020, <https://www.scmp.com/week-asia/politics/article/3089255/three-indian-soldiers-killed-clash-chinese-border-army-says>; Steven Lee Myers, “China Acknowledges 4 Deaths in Last Year’s Border Clash With India,” *The New York Times*, February 19, 2021, <https://www.nytimes.com/2021/02/19/world/asia/china-india-clash.html>.
- [2] Dinakar Peri, “Explained - The disengagement plan between India and China along the LAC.” *The Hindu*, February 15, 2021, <https://www.thehindu.com/news/national/explained-the-disengagement-plan-between-india-and-china-along-the-lac/article33841285.ece>.
- [3] Krishn Kaushik and Nirupama Subramanian, “Explained: How does the Indian army stay fighting fit at the LAC in harsh winters?” *The Indian Express*, December 5, 2020, <https://indianexpress.com/article/explained/how-the-indian-army-stays-fighting-fit-on-the-lac-in-harsh-winters-7074943/>.
- [4] Liu Zhen, “China troops settle in for Himalayan winter with hotpot deliveries and oxygen on tap,” *South China Morning Post*, November 28, 2020, <https://www.scmp.com/news/china/military/article/3111661/china-troops-settle-himalayan-winter-hotpot-deliveries-and>.
- [5] Nuclear Threat Initiative, “China,” 2015, <https://www.nti.org/learn/countries/china/nuclear/>; Nuclear Threat Initiative, “India,” 2019, <https://www.nti.org/learn/countries/india/nuclear>.
- [6] Toby Dalton, Tong Zhao and Rukmini Gupta, Rukmini, “After the Border Clash, Will China-India Competition Go Nuclear?” Carnegie Endowment for International Peace, 2020, <https://carnegieendowment.org/2020/10/29/after-border-clash-will-china-india-competition-go-nuclear-pub-83072>.
- [7] Chi Ma, Zinan Cao and Pang Xinlei, “South-to-North Water Diversion Project-5 years on.” *China Daily*, December 18, 2019, <https://www.chinadaily.com.cn/a/201912/18/WS5df95df0a310cf3e3557ec77.html>.
- [8] Daniel R. Coats, Director of National Intelligence, Statement for the Record, Senate Select Committee on Intelligence, “Worldwide Threat Assessment of the U.S. Intelligence Community,” January 19, 2019, <https://www.dni.gov/files/ODNI/documents/2019-ATA-SFR---SSCI.pdf>; Steve Brock et al., “The World Climate and Security Report 2020,” The Expert Group of the International Military Council on Climate and Security, published by the Center for Climate and Security, an Institute of the Council on Strategic Risks, 2020, <https://imccs.org/report2020/>.
- [9] Wind and temperature data from the regional climate model REMO2015. This data has a horizontal resolution of approximately 25 km and results reflect the median of 3 general circulation models (GCMs). Daily minimum temperature and daily maximum three hour wind speed are used to calculate wind chill using the formula given by the National Weather Service (<https://www.weather.gov/ffc/wci>). Values for 2010 reflect the average of 2001-2020 and values for 2040 reflect the average of 2031-2050. All model simulations included in this case study are run under the RCP 8.5 scenario.
- [10] Days with wind chill below -18°F is used as a measure of the composite adversity of wind and temperature.
- [11] Mishra, Stuti, “Uttarakhand glacier disaster: What caused the deadly flash floods in India?” *The Independent*, February 8, 2021, <https://www.independent.co.uk/news/world/asia/uttarakhand-glacier-floods-india-cause-b1799186.html>.
- [12] Lutz, A., Immerzeel, W., Shrestha, A. et al. Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. *Nature Climate Change* 4, 587-592 (2014). <https://doi.org/10.1038/nclimate2237>.
- [13] All precipitation data in this report comes from the Inter-sectoral Impact Model Intercomparison Project (ISIMIP). This daily data has a spatial resolution of 0.5° latitude and longitude and the results reflect the median of 4 models. The 99th percentile is the daily precipitation amount that is exceeded, on average, once every 100 days.

# Endnotes

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- [14] However, a limited Memorandum of Understanding governs the sharing of Chinese hydrological data with India. It covers the Brahmaputra and Sutlej rivers from May to October, and has been operational since 2013, extending an earlier agreement from 2006. Joel Wuthnow, Satu Limaye, Nilanthi Samaranyake, “Brahmaputra: A conflict-prone river takes a step backwards,” *War on the Rocks*, December 23, 2020, <https://warontherocks.com/2020/12/a-conflict-prone-river-takes-a-step-backwards/>.
- [15] Bhutan and downstream Bangladesh make up the rest. 2010 values as calculated by Woodwell Climate Research Center.
- [16] IBID; China to Build Historic Yarlung Zangbo River Hydropower Project in Tibet,” *Global Times*, November 29, 2020, <https://www.globaltimes.cn/content/1208405.shtml>.
- [17] Yao Yunsheng, Wang Qiuliang, Li Jinggang, Shen Xueling, Kong Yuyang. “Seismic hazard assessment of the Three Gorges project,” *Geodesy and Geodynamics*, Volume 4, Issue 2, May 2013: 53-60, <https://www.sciencedirect.com/science/article/pii/S1674984715300756>.
- [18] Noah J. Finnegan, Bernard Hallet, David R Montgomery, Peter K. Zeitler, John O. Stone, Alison M. Anders, & Liu Yuping. “Coupling of rock uplift and river incision in the Namche Barwa-Gyala Peri massif, Tibet,” *Geological Society of America Bulletin*, January-February 2008, volume 120: 142-155, [http://rocky.ess.washington.edu/grg/publications/pdfs/Finnegan\\_et\\_al.pdf](http://rocky.ess.washington.edu/grg/publications/pdfs/Finnegan_et_al.pdf).
- [19] Food and Agriculture Organization, *Modern Water Rights: Theory and Practice*, 2016, <http://www.fao.org/3/a-a0864e.pdf>.
- [20] Buda Su et al., “Drought losses in China might double between the 1.5 C and 2.0C warming,” *PNAS*, October 16, 2018, 115 (42): 10600-10605, <https://www.pnas.org/content/115/42/10600>.
- [21] Nilanjan Ghosh, Jayanta Bandyopadhyay, Sayanangshu Modak, “China-India Data Sharing for Early Flood Warning in the Brahmaputra: A Critique,” Issue Brief No. 328, Observer Research Foundation 2019, <https://www.orfonline.org/research/china-india-data-sharing-for-early-flood-warning-in-the-brahmaputra-58330/>.
- [22] International Energy Agency, “Implementing agreement for hydropower technologies and programs, Annex VIII, Hydropower good practices: Environmental mitigation measures and benefits,” 2006, [https://www.ieahydro.org/media/ea6123b5/annex\\_viii\\_summary\\_report.pdf](https://www.ieahydro.org/media/ea6123b5/annex_viii_summary_report.pdf).
- [23] Chandan Kumar Duarah, “Water Data Sharing Leads India-China Toward Better Trans-Boundary Water Cooperation,” *South Asia Journal*, September 26, 2018, <http://southasiajournal.net/water-data-sharing-leads-india-china-toward-better-trans-boundary-water-cooperation/>.
- [24] Monthly glacier runoff projections from the High Mountain Asia PyGEM Glacier Projections data set (<https://doi.org/10.5067/190Y84IGLIQH>) are used to calculate the seasonal cycle of the total runoff from all glaciers within the IRB. Precipitation is shown as the basin mean. Values for 2010 reflect the 2001-2020 mean, values for 2030 reflect the 2021-2040 mean, and values for 2040 reflect the 2031-2050 mean.
- [25] Lutz, A. F., Immerzeel, W. W., Shrestha, A. B., & Bierkens, M. F. P. Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. *Nature Climate Change*, 4(7) (2014): 587-592, <https://www.nature.com/articles/nclimate2237>; Yi, S., Song, C., Heki, K., Kang, S., Wang, Q., & Chang, L. Substantial meltwater contribution to the Brahmaputra revealed by satellite gravimetry. *The Cryosphere Discussions*, (2019): 1-23, <https://pdfs.semanticscholar.org/6c7e/33c528e3a0365bb9c0dca83855ee8961777c.pdf>.
- [26] Median and extreme precipitation is shown as the 50th and 99th percentile precipitation rates for each month. Glacier calculations are the same as described in Figure A1 except for BRB. Daily discharge data from ISIMIP is used to calculate the monthly maximum discharge at Guwahati. This data has a spatial resolution of 0.5° latitude and longitude and the results reflect the median of four global hydrological models, each forced by four GCMs.

# About



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Woodwell Climate Research Center (“Woodwell”) is an organization of researchers who work with a worldwide network of partners to understand and combat climate change. We bring together hands-on experience and 35 years of policy impact to find societal-scale solutions to address the climate crisis.

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**To learn more about this work, or other climate and security analyses by Woodwell and the Council on Strategic Risks, please contact:**

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